

Twenty years of change in the soil chemistry of six high elevation forest sites in Great Smoky
Mountains National Park: 1986-2006

Final Report

Submitted by:

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Introduction

In spring of 2006, we studied the impacts of air pollution on high elevation forests by collecting soil samples from six sites in Great Smoky Mountains National Park (GSMNP) where soils were first collected and analyzed in 1986 as part of the Direct/Delayed Response Project (DDRP), a cooperative study between the Environmental Protection Agency and a large team of cooperators including the Oak Ridge National Laboratory. The DDRP evaluated the long-term chemical response of watersheds and surface waters to acidic deposition. The DDRP watersheds were located in regions of the eastern United States known to contain surface waters with low acid neutralizing capacity (ANC), including the southern Appalachian Mountains. By comparing changes in soil chemistry, we examined whether two decades of acid deposition has increased soil acidity and caused the loss of nutrients. In addition to providing important information to the National Park Service, this project also involved college interns as an integral part of a scientific study. Two interns were involved in the sampling of all sites and preparation of samples for analysis. In addition, during this project the interns had the opportunity to interact with a variety of scientists who were experts in the fields of forest ecology, soil science, and archaeology. Additionally, this project served as a starting point for a continued study of high-elevation soil chemistry that will continue to involve student interns.

Methods

At each of the six study sites, we dug a pit and collected soil from all horizons using the same field methods as the original 1986 survey. All samples were sent to certified soil testing laboratories and analyzed using the same techniques as the 1986 survey. To evaluate changes at the six sites, we examined four aspects of soil chemistry in this report: (1) pH, (2) exchangeable aluminum (Al), (3) calcium (Ca) content, and (4) nitrogen (N) content. These parameters were examined for both the surface soil (A horizon) and the subsoil (B horizon). We also examined how Al and pH of the A horizon have changed through time across an elevation gradient. If soils have become more acidic between the late 1980s and 2006, we would expect lower pH, greater exchangeable Al, less soil Ca, and greater soil N. Soil N increases as a result of N deposition, and increased deposition of N and sulfur (S) causes increased soil acidity, which lowers soil pH.

Decreased pH causes Ca to be leached (or lost) from the soil and Al held within the soil to be released for uptake by plants. Once released into the soil-water solution, Al is very toxic to plants.

Results

Surface soils exhibited less change in pH and Al concentration than subsoils (Figure 1). We found that surface soil pH decreased at two sites, remained largely unchanged at three sites, and increased at one site (Figure 1). Surface soil Al concentration increased at three sites, decreased at two sites, and remained largely unchanged at one site. Subsoil pH decreased at five out of six sites and Al increased at four out of six sites. Generally, pH reductions and Al increases were greater in the subsoil than the surface soil. The reduction in subsoil pH was the only statistically significant change we found in the data (paired t-test, $p = 0.044$). Because of our small sample size ($n = 6$) we had limited statistical power and a limited ability to detect differences that may actually exist.

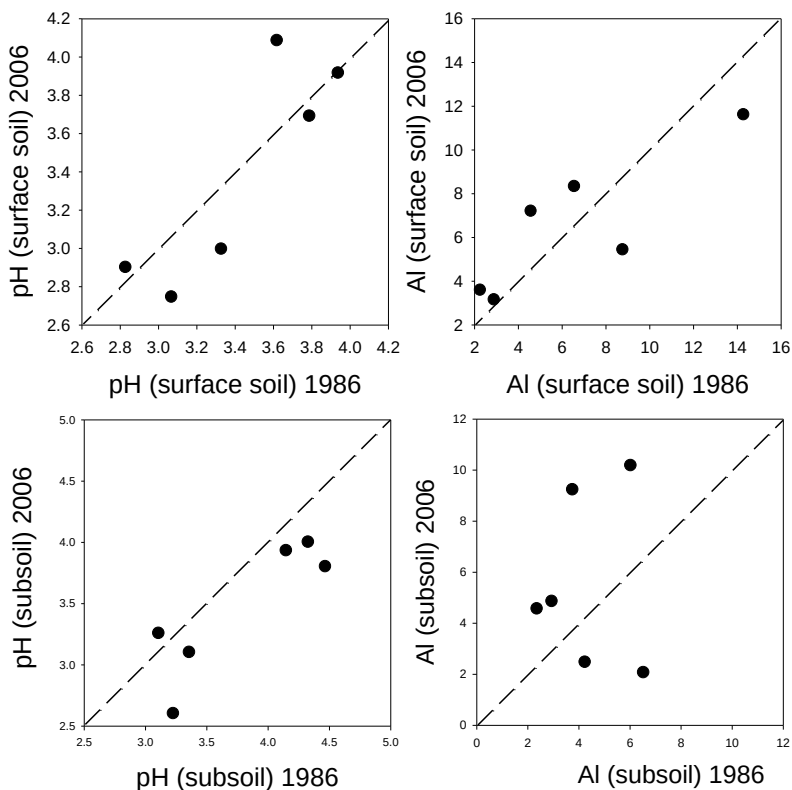


Figure 1. pH and Aluminum concentrations (meq/100 g) of surface and subsoil samples in 1986 and 2006. The dotted line indicates a 1-to-1 relationship between years. Samples that fall below the line decreased between years, those that fall above increased.

Surface soils also exhibited less change in Ca and N concentration than subsoils (Figure 2). Soil Ca in the surface soil decreased slightly at two sites, remained largely unchanged at two sites, and increased at one site. Generally soil samples contained little calcium, regardless of sample year. Nitrogen in the surface soil decreased slightly at four sites and increased at two sites. Trends in the subsoil suggest greater effects of acidification. Subsoil Ca decreased greatly at four out of six sites. Subsoil N increased at two sites, decreased at three sites, and remained largely unchanged at one site.

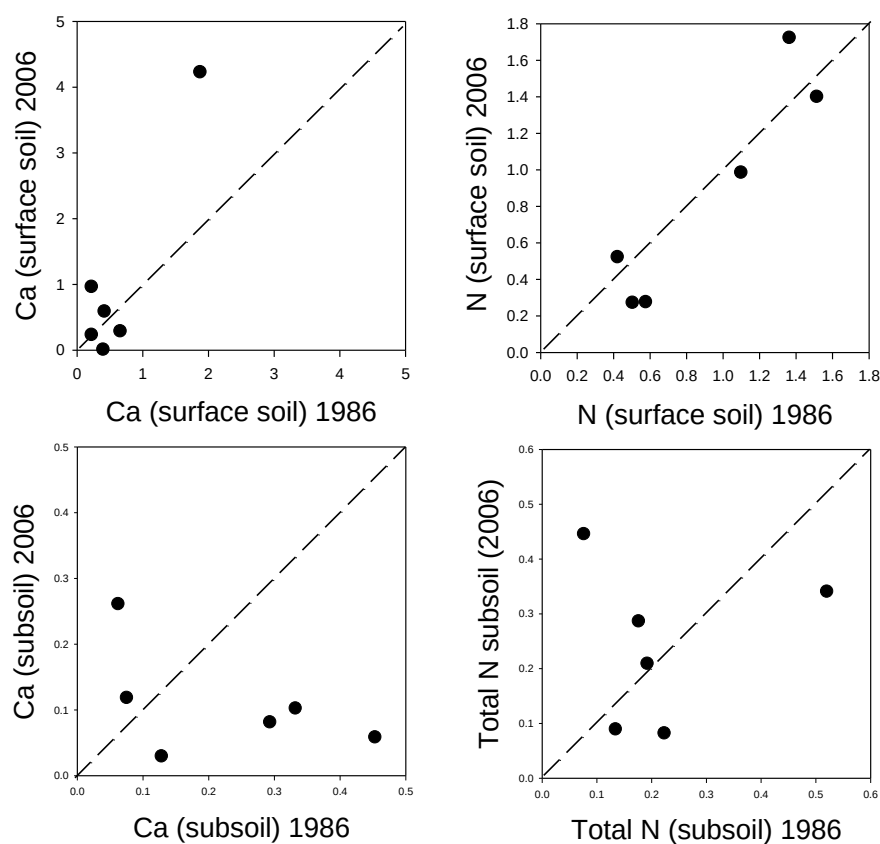


Figure 2. Calcium (Ca) and Nitrogen (N) concentrations (meq/100 g) of surface and subsoil samples in 1986 and 2006. The dotted line indicates a 1-to-1 relationship between years. Samples that fall below the line decreased between years, those that fall above increased.

Our results revealed differing trends in soil chemistry with increasing elevation between surface soils and subsoils (Figures 3 and 4). In 1986, surface soil Al exhibited a marked peak between 1500 and 1600 m elevation. In 2006, this peak was reduced but still evident, and surface soil Al concentrations were greater at elevations above 1600 m. In 1986, surface soil pH was high between 1350-1450 m, exhibited a clear nadir at approximately 1500 m elevation, but increased again between 1650 and 1750 m elevation. In 2006, this same general trend was evident, but pH was lower on the plot located at 1650 m elevation.

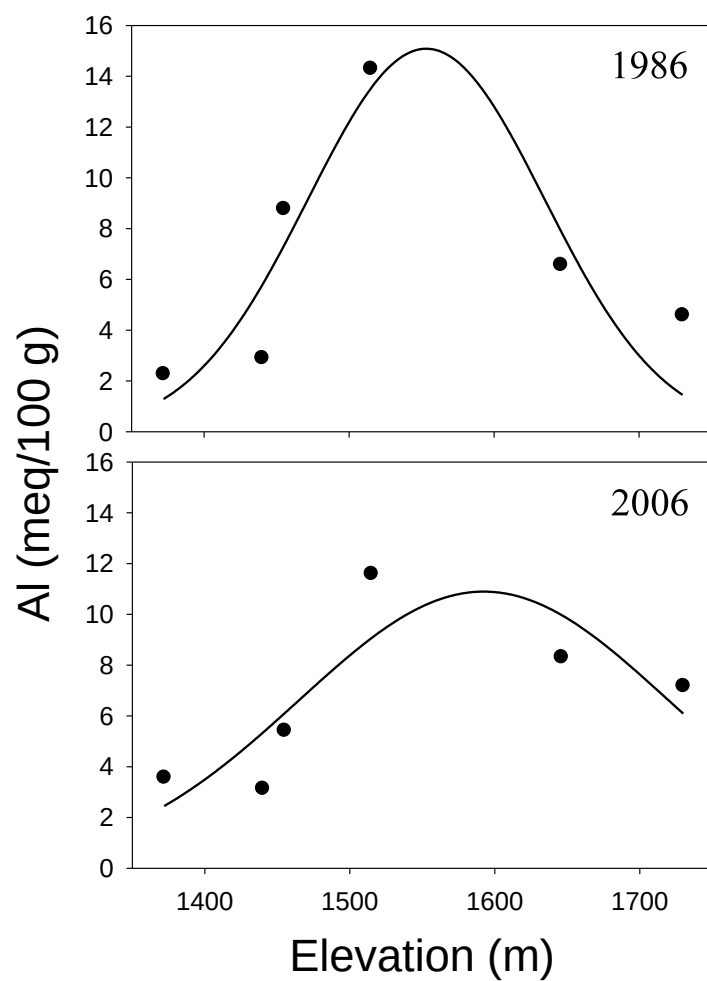


Figure 3. Aluminum (Al) concentration of the surface soil vs. elevation for both sample years (1986 and 2006).

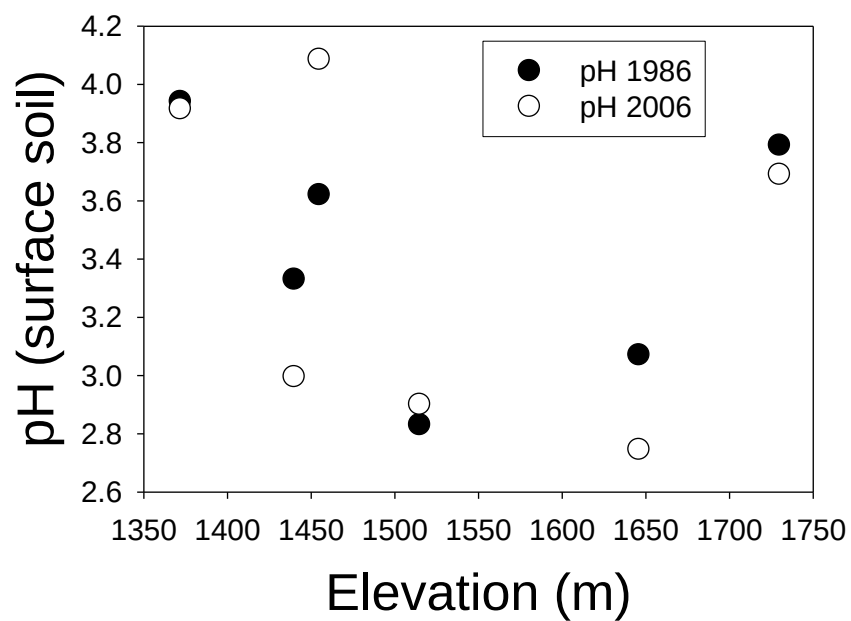


Figure 4. pH of the subsoil vs. elevation for both sample years (1986 and 2006).

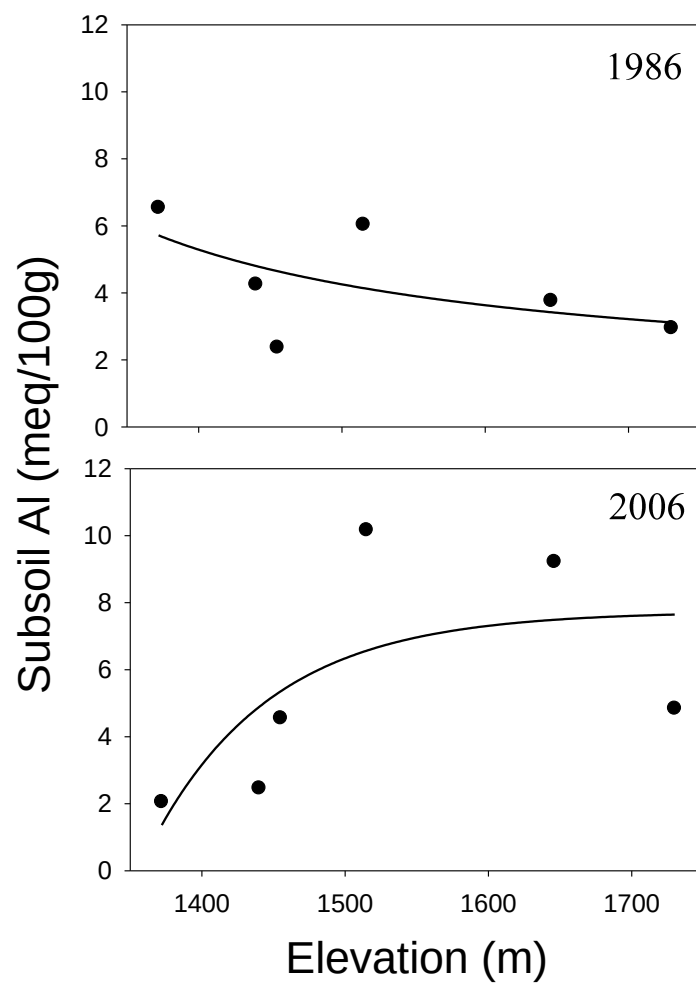


Figure 5. Aluminum (Al) concentration of the subsoil vs. elevation for both sample years (1986 and 2006).

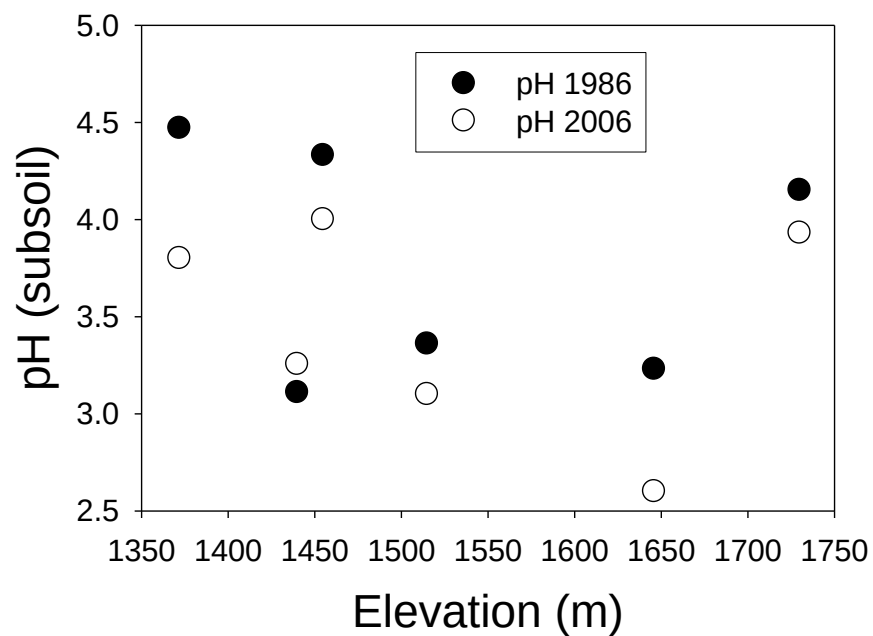


Figure 6. pH of the subsoil vs. elevation for both sample years (1986 and 2006).

Conclusions

Although the small sample size of this study resulted in limited statistical power, our results do show potential trends in soil chemistry between 1986 and 2006. First, the surface soil and subsoil exhibited differing trends. Generally, our results suggest that the surface soil has experienced little change in chemistry between 1986 and 2006. The subsoil, however, appears to have reduced pH, greater Al, and reduced Ca. Further, the relationship between elevation and surface soil Al and pH were similar for both 1986 and 2006. Aluminum concentration in the subsoil decreased with elevation in the 1986 sample, but increased with elevation in the 2006 sample.

Because of our small sample size, concrete conclusions about the effects of acid deposition on high-elevation soil chemistry are not possible. However, this study has suggested areas for further study. Currently, we plan to collect and analyze more samples at each site to insure that the data and trends represented in the 2006 samples are correct. We also plan to sample a range of additional sites across elevations to confirm that trends we observed between elevation and soil chemistry in 2006 are repeatable. Finally, we are establishing sample sites to determine if trends we observed in this and other studies are correlated with soil solution (water) chemistry. This will help us to better link the results of this and other high-elevation studies to changes in vegetation.